

Research Paper ■

Electronic Screening of Dictated Reports to Identify Patients with Do-Not-Resuscitate Status

DOMINIK ARONSKY, MD, PhD, EVELYN KASWORM, BS, JAY A. JACOBSON, MD, PETER J. HAUG, MD, NATHAN C. DEAN, MD

Abstract **Objective:** Do-not-resuscitate (DNR) orders and advance directives are increasingly prevalent and may affect medical interventions and outcomes. Simple, automated techniques to identify patients with DNR orders do not currently exist but could help avoid costly and time-consuming chart review. This study hypothesized that a decision to withhold cardiopulmonary resuscitation would be included in a patient's dictated reports. The authors developed and validated a simple computerized search method, which screens dictated reports to detect patients with DNR status.

Methods: A list of concepts related to DNR order documentation was developed using emergency department, hospital admission, consult, and hospital discharge reports of 665 consecutive, hospitalized pneumonia patients during a four-year period (1995–1999). The list was validated in an independent group of 190 consecutive inpatients with pneumonia during a five-month period (1999–2000). The reference standard for the presence of DNR orders was manual chart review of all study patients. Sensitivity, specificity, predictive values, and nonerror rates were calculated for individual and combined concepts.

Results: The list of concepts included: *DNR*, *Do Not Attempt to Resuscitate (DNAR)*, *DNI*, *NCR*, *advanced directive*, *living will*, *power of attorney*, *Cardiopulmonary Resuscitation (CPR)*, *defibrillation*, *arrest*, *resuscitate*, *code*, and *comfort care*. As determined by manual chart review, a DNR order was written for 32.6% of patients in the derivation and for 31.6% in the validation group. Dictated reports included DNR order-related information for 74.5% of patients in the derivation and 73% in the validation group. If mentioned in the dictated report, the combined keyword search had a sensitivity of 74.2% in the derivation group (70.0% in the validation group), a specificity of 91.5% (81.5%), a positive predictive value of 80.9% (63.6%), a negative predictive value of 88.0% (85.5%), and a nonerror rate of 85.9% (77.9%). *DNR* and *resuscitate* were the most frequently used and *power of attorney* and *advanced directives* the least frequently used terms.

Conclusion: Dictated hospital reports frequently contained DNR order-related information for patients with a written DNR order. Using an uncomplicated keyword search, electronic screening of dictated reports yielded good accuracy for identifying patients with DNR order information.

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Resuscitating people with sudden cardiac or respiratory arrest using closed-chest compression and mouth-to-mouth ventilation was introduced formally in 1960.¹ Since then, cardiopulmonary resuscitation efforts have become part of standard clinical care for hospitalized patients who suffer a cardiac or respiratory arrest. However, clinicians, patients, and families decide to forego resuscitation in certain situations.²

Discussion about end-of-life issues has gained increased attention in medical and lay publications. Medical societies and other organizations have issued consensus statements, and legislation has codified patient autonomy in end-of-life decisions in the Patient Self-Determination Act.^{3,4} Patients can specify their medical care for end-of-life situations in an advanced directive document, such as a living will or a durable power of attorney for health care. Physicians may honor a patient's request to limit aggressive treatment by writing a do-not-resuscitate (DNR) order. Cardiopulmonary resuscitation may be the only medical procedure that does not require a physician's order, but requires an order to withhold it.⁵ Because of the public's increased awareness of end-of-life issues, advance directives and DNR orders are increasingly discussed and documented in the hospital setting.⁶ DNR orders are written for 18% to 28% of hospitalized patients and for up to 70% of hospitalized patients at the time of death.^{5,6}

As advance directives and DNR orders have fundamental implications for patient care, the discussions about end-of-life treatment options between the physician and the patient or the patient's family are documented in the patient's chart. The documentation of a DNR order usually consists of hand-written notes on order sheets, handwritten progress

Affiliations of the authors: Departments of Biomedical Informatics & Emergency Medicine, Vanderbilt University, Nashville, TN (DA); Division of Medical Ethics (EK, JAJ), Department of Medical Informatics (PJH), Division of Pulmonary Medicine (NCD), LDS Hospital, University of Utah, Salt Lake City, UT.

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Correspondence and reprints: Dominik Aronsky, MD, PhD, Department of Biomedical Informatics, Eskin Biomedical Library, Vanderbilt University Medical Center, 2209 Garland Avenue, Nashville, TN 37232-8340; e-mail: <dominik.aronsky@vanderbilt.edu>.

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notes, designated procedure-specific paper-based forms, or references to discussions and decisions in unstructured dictated reports.

Investigators need to identify patients with DNR orders in retrospective research studies that intend to exclude patients with DNR orders, because they may experience different care and outcomes that bias study results. Studies that focus on end-of-life issues should identify all DNR patients in the study population. As long as electronic documentation of advanced directives and DNR orders remains the exception,⁷⁻⁹ identifying patients with DNR orders remains challenging and generally requires costly and time-consuming manual chart review.

Due to the common use of DNR orders and a heightened focus on appropriate documentation, we hypothesized that DNR orders are mentioned in the dictated reports that enter the computerized patient record. This study examined whether a simple, computerized keyword search of dictated reports is able to identify patients with DNR orders.

Materials and Methods

The study was performed at LDS Hospital, Salt Lake City, Utah, a tertiary care, university-affiliated hospital with 540 beds. LDS Hospital uses an integrated clinical information system (HELP System) for documenting, reporting, and supporting physicians with a variety of computerized clinical decision support systems.¹⁰ This analysis was based on information collected for two studies, the primary goal of which was to examine processes related to the delivery of pneumonia care and the evaluation of a computerized pneumonia decision support system.¹¹ The study included all adult patients with pneumonia who were seen initially in the emergency department and subsequently admitted to the hospital during two separate study periods. Patients from the first, four-year long study period (June 1995–June 1999) were used in the derivation group. Patients from the second, five-month study period (November 1999–April 2000) were included in the validation group. For patients in the derivation group, the definition of community-acquired pneumonia included an ICD-9 code of pneumonia and a chest x-ray report compatible with pneumonia as determined by the majority vote of three physician reviewers. In the validation group, patients with community-acquired pneumonia were identified using a three-step review process, which has been described previously.¹² In summary, the process reviewed all emergency department encounters during the study period and applied increasingly stringent criteria on each step to exclude patients with only a remote chance of having pneumonia. The third step included a panel of three physicians who reviewed the patients' chart and radiology films and determined whether pneumonia was present or absent. The study was approved by the local Institutional Review Board and Research and Human Rights Committee.

Do-Not-Resuscitate Orders

To establish a reference standard for resuscitation status, one author manually reviewed the paper charts of all patients during the two study periods using a standardized abstraction form. Data abstraction included whether a written DNR order was present and whether DNR order information was mentioned in dictated reports. During the first study pe-

riod, the Division of Medical Ethics instituted a procedure-specific paper-based DNR form and promoted its use through educational instruction.¹³ The DNR form was slightly larger than regular-sized paper and had a colored edge to make it visible and easy to locate in a patient's chart. A DNR order was considered present if there was a written order in the patient's medical chart during the hospitalization. The mentioning of a DNR order in a dictated report was insufficient if a written DNR order was not actually present in the chart.

Among patients without a DNR order, we identified those patients who had actions described in the chart consistent with a DNR order. An example would be a patient without an explicit DNR order but with documentation that describes withdrawing of life-sustaining interventions and providing comfort measures only.

The performance of an electronic screening method can only be evaluated if information is available in computable format. For example, if DNR status information is noted in handwritten progress notes only and unavailable in electronic format, a keyword search will not be able to detect patients with a DNR order. In these instances, electronic screening for DNR orders in dictated reports will fail. However, failure to detect such cases does not provide information about the quality of electronic screening of concepts but rather reflects the documentation practices. To evaluate the keywords used to identify patients with a DNR order, we performed a second analysis. For this second analysis, the reference standard included patients who had DNR order information both in paper-based (e.g., DNR order form, progress report) and electronic form (dictated reports).

Selection of Keywords

A list of DNR-related keywords was developed using the derivation population and reviewed in group discussions. The list of keywords included terms that are directly and indirectly related to DNR order information. In addition, the list of keyword searches was submitted to a Unified Medical Language System (UMLS) search to identify possible abbreviations and synonyms.¹⁴ For common abbreviations, the fully spelled term, such as *do not resuscitate* for DNR, was included. Fully spelled terms were searched in truncated format (indicated by using the symbol "\$") to allow for different deviations of a root term. For example, the truncated term *resusc\$* includes concepts such as *resuscitate*, *resuscitation*, *resuscitated*, or *resuscitative*. Variants of keywords, such as concatenation of keywords by dashes (*Do Not Resuscitate* and *Do-Not-Resuscitate*), or the use of punctuation (*DNR* and *D.N.R.*), were also considered. We did not consider variants that may have occurred due to misspelled terms in dictated reports. For abbreviations, we evaluated the shortest term possible but added leading or trailing blank spaces if the abbreviation was a substring of other frequently used terms. This approach was used for the keyword *NCR* (no cardiopulmonary resuscitation), which is a substring of the term *iNCRease\$* or *paNCReat\$*, and the keyword *POA* (power of attorney), which is a substring of *hyPOActiv\$* or *hyPOAlbumin\$*. Because the concept *resuscitation* appeared frequently in the context of *fluid resuscitation*, we specifically excluded the concept *fluid resuscitation*. Similarly, we excluded the term *full code* when searching for the concept *code*. The evaluated keywords are listed in Table 1.

Table 1 ■ Concepts, Search Terms, and Variations Used to Identify DNR Patients

Concept	Search Term	Variants
DNR	DNR	Includes punctuation
	Do not resusc\$	Includes dashes
	To be resusc\$	Includes "not to be resusc\$"
	To be not resusc\$	Includes dashes
	To not be resusc\$	Includes dashes
DNAR	DNAR	Includes punctuation
	Do not attempt	Includes dashes
DNI	DNI	Includes punctuation
	Do not intub\$	Includes dashes
	Not be intub\$	Includes dashes
	Not to be intub\$	Includes dashes
	Be not intub\$	Includes dashes
NCR	_NCR or NCR_	Includes punctuation
	No cardiopulmonary	
	No-cardiopulmonary	
	No cardio-pulmonary	
	No-cardio-pulmonary	
	No cardio pulmonary	
	No chest compr\$	
	No cardiac compr\$	
Advanced directives	\$ced dire\$	
Living will	Living will	
Power of attorney	_POA or POA_	Includes punctuation
	\$er of att\$	Includes dashes
CPR	CPR	Includes punctuation
	Cardio pulmonary resusc\$	Includes dashes
	Cardiac resusc\$	
	Cardiac compr\$	
	Chest compr\$	
Defibrillation	Defibrill\$	
Arrest	Arrest	
	\$ac arres\$	
	\$ory arres\$	
Resuscitate	Resusc\$	Excludes "fluid resusc\$"
Code	Code status	Excludes "full code"
Comfort care	Comfort care	

NOTE: The \$ symbol indicates the truncation of a term. The underscore symbol ("_") indicates the explicit use of a leading or trailing blank space.

DNR = do not resuscitate; DNAR = do not attempt to resuscitate; DNI = do not intubate; NCR = no cardiopulmonary resuscitation; CPR = cardiopulmonary resuscitation.

In addition, we examined whether claims data could be used to identify patients with DNR orders and augment the identification rate when combined with keywords. Although ICD-9 codes do not exist for DNR information (the explicit withholding of a procedure), surrogate codes exist that might indicate that a life-supporting discussion has occurred with the patient or the family. We applied a previously used list of ICD-9 codes¹⁵: 427.5 (cardiac arrest), 427.41 (ventricular fibrillation), 427.1 (ventricular tachycardia), 996.2 (defibrillation), and 996 (cardiopulmonary resuscitation).

Dictated Reports

All dictated reports are stored electronically in the clinical information system. Due to their likelihood of mentioning a DNR order, the following dictated reports were examined for DNR order status: emergency department reports (includ-

ing addenda), hospital admission reports, consultations, and hospital discharge notes (including death summaries).

Outcome Variables

We computed standard test characteristics for the derivation and validation groups. The test characteristics included sensitivity, specificity, positive and negative predictive values, and nonerror rates. They were determined for each term individually and for the combination of all DNR order-related keywords. Sensitivity was determined by dividing the number of patients who had a DNR order and a keyword present by the total number of patients with a DNR order. Specificity was calculated by dividing the number of patients without a DNR order and without the keyword present by the total number of patients without a DNR order. Positive predictive value was determined by dividing the number of patients with a DNR order and a keyword present by the number of all patients with the keyword present. Negative predictive value was calculated by dividing the number of all patients without a DNR order and without the keyword present by the total number of patients without the keyword present. The nonerror rate provides an overall accuracy measure. The nonerror rate is the sum of patients with a DNR order and the keyword present (true-positive rate) and the patients without a DNR order and without the keyword present (true-negative rate) divided by all patients.

We calculated 95% confidence intervals for the differences of proportions between the derivation and validation group. Because values in the 2 × 2 matrices included small numbers and resulted in proportions smaller than 10% and larger than 90%, we calculated confidence intervals following the methods proposed by Newcombe.¹⁶

Results

The derivation group included 665 pneumonia patients (female, 46.8%; mean age, 66.7 ± 19.8 years; in-hospital mortality rate, 8.1%) and 190 validation group patients (female, 50%; mean age, 66.9 ± 17.2 years; in-hospital mortality rate, 8.9%). Five patients were excluded because their charts were not available. The number and category of dictated reports are shown in Table 2.

Figure 1 shows the categorization of patients for both groups as determined by manual chart review. In the derivation group, a DNR order was written for 217 (32.6%) patients (female, 54.4%; mean age, 79.9 ± 12.8 years; mortality rate, 24.9%). DNR order information was present in dictated reports for 161 patients (74.5%). Compared with the derivation population, the patients in the validation group had similar descriptive DNR order characteristics. Of the 54 patients who died, 46 (85%) had a DNR order written, and 171 (28.0%) DNR orders were written for the 611 patients who survived. In the validation group, a DNR order was written

Table 2 ■ Availability of Dictated Reports

Type of Report	Derivation (n = 665)	Validation (n = 190)
Emergency department report	97.1%	98.9%
Hospital admission report	92.2%	94.2%
Consultation report	22.0%	31.1%
Hospital discharge report	95.0%	94.7%

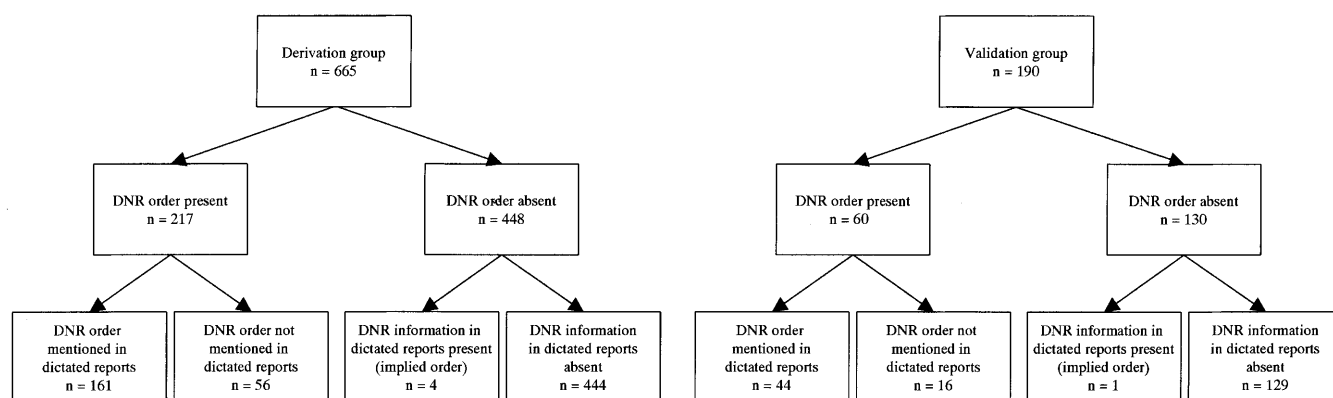


Figure 1. Flow diagram of patients, DNR order status, and order documentation in dictated reports.

for 60 (31.6%) patients (female, 52%; mean age, 78.1 ± 10.7 years; mortality rate, 23.3%). There were 44 DNR orders (73%) mentioned in the dictated reports. Of the 17 patients who died, 14 (82%) had a DNR order written, and 46 (26.6%) DNR orders were written for the 173 patients who survived. Among patients without a DNR order, four patients in the derivation and one patient in the validation group had an implied DNR order. In these patients, clinical care was compatible with following a DNR order, but no DNR order was written.

In the derivation group, keywords appeared 444 times in 199 different patients. The occurrence of keywords ranged from 1 to nine different concepts and averaged 2.2 per patient. In the validation group, keywords were mentioned 168 times in 66 different patients. The frequency of concepts ranged from 1 to eight and averaged 2.5 per patient. *DNR* and *resuscitate* were the most frequently dictated and *power of attorney* and *advanced directives* the least frequently dictated terms in both groups. Despite the fact that *DNAR* (do-not-attempt-to-resuscitate) is explicitly used on the institutional DNR order form, it was never mentioned in either group. The overall occurrence of concepts was comparable between the derivation and validation group.

Performance measures for individual concepts are shown in Table 3. They ranged considerably when compared against the reference standard, which included patients without DNR order information in the dictated reports. *DNR*, *resuscitation*, and *code* were the most sensitive terms. *DNI* and *comfort care* had the highest positive predictive value in both groups. In both groups, the term *arrest* never occurred isolated and did not increase the number of identified patients with a DNR order. The nonerror rate for individual concepts ranged between 68.1% and 79.5% for the derivation (with *power of attorney* being an exception) and between 66.8% and 82.6% for the validation group (Table 3).

With respect to individual concepts, ICD-9 codes had relatively poor performance characteristics (Table 3). Based on the sole presence of an ICD-9 code, an additional three patients with a DNR order were identified in the derivation group; in the validation group the ICD-9 codes did not identify any additional patients.

When all keywords were combined and compared against the reference standard, the sensitivities in the derivation

and validation group were 74.2% and 70.0% (95% confidence interval of difference [CI]: -0.077 – 0.178), the specificities 91.5% and 81.5% (CI: 0.035 – 0.178), the positive predictive values 80.9% and 63.6% (CI: 0.051 – 0.303), the negative predictive values 88.0% and 85.5% (CI: -0.036 – 0.102), and the nonerror rates 85.9% and 77.9% (CI: 0.019 – 0.148).

The results of the second analysis, which examined the ability of the keywords to identify DNR patients when DNR order information was available in electronic format, are shown in Table 4. The nonerror rate for individual concepts ranged between 76.1% and 88% for the derivation group and between 75.3% and 91.1% for the validation group.

For the second analysis the combined search using all keywords resulted in sensitivities of 96.3% in the derivation and 93.2% in the validation group (CI: -0.03 – 0.147), specificities of 91.3% and 89.7% (CI: -0.033 – 0.079), positive predictive values of 77.9% and 73.2% (CI: -0.07 – 0.185), negative predictive values of 98.7% and 97.8% (CI: -0.011 – 0.051) and nonerror rates of 92.5% and 90.5% (CI: -0.021 – 0.073). The combined keyword search missed only six (false-negative cases) of 161 patients in the derivation and three of 44 patients in the validation group. Examples for missed DNR order-related information included: *withdraw life support measures*, *[the patient] desired no heroic measures or mechanical support measures including ventilation or chest compressions*, and *they [the family members] decided to withdraw support*. Among the five patients with an implied DNR order (DNR order information mentioned in the dictated report, but no written order), the combined keyword search identified three of five patients.

Discussion

Our evaluation of a large pneumonia population showed that an uncomplicated search algorithm can identify patients with a documented DNR order in a dictated report. The test characteristics for single concepts varied considerably and were relatively low, indicating that different concepts are used to describe DNR orders in dictated reports. However, a combined search using multiple keywords had high overall accuracy in identifying patients with DNR order information in electronically available reports. The list of keywords represents a practical and cost-effective approach to screening dictated reports for the presence of DNR order information.

Table 3 ■ Performance Measures of Concepts if a DNR Order Was Present

Concept	Frequency		Sensitivity			Specificity			Positive Predictive Value			Negative Predictive Value			Nonerror Rate		
	Deriv	Valid	Deriv	Valid	CI	Deriv	Valid	CI	Deriv	Valid	CI	Deriv	Valid	CI	Deriv	Valid	CI
DNR	85	37	38.2	53.3	-0.286 to -0.01	99.6	96.2	0.009 to 0.083	97.6	86.5	-0.016 to 0.257	76.9	81.7	-112 to 0.028	79.5	82.6	-0.088 to 0.039
DNI	14	15	6.5	23.3	-0.293 to -0.071	100	99.2	-0.003 to 0.042	100	93.3	-0.156 to 0.298	68.8	73.7	-0.119 to 0.029	69.5	75.3	-0.124 to 0.016
NCR	62	11	26.3	16.7	-0.03 to 0.192	98.9	99.2	-0.019 to 0.032	91.9	90.9	-0.11 to 0.3	73.5	72.1	-0.057 to 0.092	75.2	73.2	-0.047 to 0.094
Advance directives	7	3	2.8	3.3	-0.087 to 0.034	99.8	99.2	-0.007 to 0.04	85.7	66.7	-0.269 to 0.664	67.9	69.0	-0.082 to 0.067	68.1	68.9	-0.08 to 0.069
Living will	14	9	5.5	13.3	-0.0189 to -0.003	99.6	99.2	-0.01 to 0.038	85.7	88.9	-0.304 to 0.308	68.5	71.3	-0.099 to 0.05	68.9	72.1	-0.101 to 0.043
CPR	49	16	19.4	20.0	-0.133 to 0.094	98.4	96.9	-0.01 to 0.062	85.7	75.0	-0.086 to 0.362	71.6	72.4	-0.08 to 0.07	72.6	72.6	-0.068 to 0.075
Defibrillation	10	9	3.7	11.7	-0.186 to -0.012	99.6	98.5	-0.005 to 0.05	80.0	77.8	-0.326 to 0.378	68.1	70.7	-0.098 to 0.052	68.3	71.1	-0.098 to 0.048
Arrest	38	11	10.1	6.7	-0.064 to 0.097	96.4	94.6	-0.017 to 0.073	57.9	36.4	-0.108 to 0.0471	68.9	68.7	-0.072 to 0.081	68.3	66.8	-0.058 to 0.092
Resuscitate	84	34	31.8	30.0	-0.12 to 0.138	96.7	87.7	0.039 to 0.158	82.1	52.9	0.109 to 0.467	74.5	73.1	-0.059 to 0.096	75.5	69.5	-0.01 to 0.136
Code	54	19	21.7	25.0	-0.165 to 0.076	98.4	96.9	-0.01 to 0.062	87.0	78.9	-0.089 to 0.313	72.2	73.7	-0.086 to 0.063	73.4	74.2	-0.075 to 0.066
Power of attorney	5	0	1.8	0.0	-0.043 to 0.046	99.2	100	-0.046 to 0.021	80.0	N/A	N/A	35.5	68.4	-0.409 to -0.242	36.1	68.4	-0.402 to -0.236
Comfort care	22	4	10.1	6.7	-0.064 to 0.097	100	100	-0.009 to 0.029	100	100	-0.149 to 0.049	69.7	69.9	-0.074 to 0.075	70.7	70.5	-0.069 to 0.078
ICD-9 code	35	6	6.0	1.7	-0.033 to 0.085	95.1	96.2	-0.043 to 0.04	37.1	16.7	-0.216 to 0.419	67.6	67.9	-0.077 to 0.076	66.0	66.3	-0.076 to 0.075

Values are in percent. The concept "DNAR" (do-not-attempt-to-resuscitate) was never used and, therefore, not included in the table.

Deriv = derivation group; Valid = validation group; CI = 95% confidence interval around the difference between the proportions of the derivation group and the validation group; DNR = do not resuscitate; DNI = do not intubate; NCR = no cardiopulmonary resuscitation; CPR = cardiopulmonary resuscitation.

The high specificity and high negative predictive value of the combined search indicate that DNR order information is more frequently available in dictated reports when DNR orders are written. In the absence of a documented patient-provider discussion about end-of-life issues, full life support remains an implicit notion of the patient's preference. For certain applications, high sensitivity is needed to find all patients with DNR order information. In such situations, the list of keywords may include additional terms or combinations of terms that may indicate the presence of DNR order-related information but are more frequently used in a different context and may result in many false-positive results. An example of such a term includes the concept *withdrawal*, which is frequently used in the context of alcohol abuse.

Documentation, reporting, and communication of DNR order information and patient preferences varies among clinicians. For about 25% of patients in both cohorts, DNR orders were written during the patient's hospitalization but not mentioned in any dictated reports. For these patients, electronic screening of dictated reports needs to be augmented by manual chart review.

Documentation of patients' end-of-life preferences occurs throughout the spectrum of health care. A feasible and simple approach to easily identify such patients retrospectively does not currently exist but is necessary in a variety of situations. Patients with DNR orders frequently need to be identified and excluded in retrospective studies. These patients represent a population with different characteristics that may con-

found outcome variables. In prospective studies, a prevalence estimate of patients with DNR orders who subsequently need to be excluded from the study cohort is useful for study planning purposes. The examination of large clinical datasets may benefit from a feasible and cost-effective approach to electronically screen for DNR patients. Studies that focus on end-of-life and DNR order-related issues could identify patients across different diseases and settings. Lastly, the keyword search may support audit functions to monitor and understand the patterns of DNR order documentation within an institution.

We believe that our methodology to identify DNR orders from text-based documents is primarily applicable to retrospective data analyses. Although it is conceivable to create a real-time decision support system that is based on a keyword search of available narrative documents and prompts clinicians to place or initiate a discussion with the patient about a DNR order, there are important ethical and legal implications that require careful consideration about pursuing such an approach. For clinical purposes, it is not possible to access the most current DNR status information through an electronic search if the most current document is only paper based.

Natural language understanding tools have been successfully applied for mining and extracting information from text-based documents.¹⁷⁻¹⁹ They are particularly helpful in situations that require the semantic interpretation of a phrase, sentence, lexical variant, or negated finding to infer the

Table 4 ■ Performance Measures of Concepts if a DNR Order Was Mentioned in the Dictated Reports

Concept	Frequency		Sensitivity			Specificity			Positive Predictive Value			Negative Predictive Value			Nonerror Rate		
	Deriv	Valid	Deriv	Valid	CI	Deriv	Valid	CI	Deriv	Valid	CI	Deriv	Valid	CI	Deriv	Valid	CI
DNR	85	37	51.0	72.7	−0.345 to −0.047	99.6	96.2	0.008 to 0.074	97.6	86.5	0.016 to 0.257	86.6	81.0	−0.101 to 0.003	88.0	91.1	−0.073 to 0.023
DNI	14	15	6.7	31.8	−0.383 to −0.101	100	99.3	−0.003 to 0.038	100	93.3	−0.156 to 0.298	77.4	82.9	−0.114 to 0.015	77.9	83.7	−0.114 to 0.008
NCR	62	11	35.4	22.7	−0.032 to 0.252	99.0	99.3	−0.017 to 0.028	91.9	90.9	−0.11 to 0.3	82.8	81.0	−0.043 to 0.087	83.6	81.6	−0.037 to 0.087
Advance directives	7	3	3.7	4.5	−0.116 to 0.045	99.8	99.3	−0.006 to 0.036	85.7	66.7	−0.269 to 0.664	76.4	77.5	−0.075 to 0.061	76.5	77.4	−0.072 to 0.063
Living will	14	9	7.5	18.2	−0.249 to −0.007	99.6	99.3	−0.009 to 0.034	85.7	88.9	−0.304 to 0.308	77.1	80.1	−0.092 to 0.041	77.3	80.5	−0.092 to 0.037
CPR	49	16	24.2	27.3	−0.188 to 0.1	98.0	97.3	−0.016 to 0.049	79.6	75.0	−0.153 to 0.307	80.2	81.6	−0.075 to 0.057	80.2	81.1	−0.068 to 0.059
Defibrillation	10	9	4.3	13.6	−0.226 to −0.008	99.4	97.9	−0.003 to 0.053	70.0	66.7	−0.337 to 0.4	76.5	79.0	−0.088 to 0.047	76.4	78.4	−0.083 to 0.051
Arrest	38	11	12.4	9.1	−0.095 to 0.115	96.4	95.2	−0.019 to 0.062	52.6	36.4	−0.159 to 0.422	77.5	77.7	−0.066 to 0.072	76.1	75.3	−0.057 to 0.081
Resuscitate	84	34	41.0	40.9	−0.157 to 0.16	96.6	89.0	0.03 to 0.138	79.8	52.9	0.084 to 0.446	83.8	83.3	−0.055 to 0.077	83.3	77.9	0.007 to 0.124
Code	54	19	0.6	34.1	−0.216 to 0.088	98.4	97.3	−0.011 to 0.053	85.2	78.9	−0.011 to 0.296	81.2	83.0	−0.078 to 0.051	81.5	82.6	−0.068 to 0.055
Power of attorney	5	0	2.5	0.0	−0.057 to 0.062	99.8	100	−0.011 to 0.024	80.0	N/A	N/A	76.2	76.8	−0.07 to 0.066	76.2	76.8	−0.07 to 0.066
Comfort care	22	4	12.4	9.1	−0.095 to 0.115	99.6	100	−0.014 to 0.022	90.9	100	−0.278 to 0.403	78.1	78.5	−0.067 to 0.067	78.5	78.9	−0.066 to 0.065
ICD-9 code	35	6	5.6	0.0	−0.029 to 0.103	94.8	96.1	−0.043 to 0.035	25.7	0	−0.15 to 0.421	75.9	76.8	−0.074 to 0.063	73.2	74.5	−0.078 to 0.06

All values in percent. The concept “DNAR” (do-not-attempt-to-resuscitate) was never used and, therefore, not included in the table.

Deriv = derivation group; Valid = validation group; CI = 95% confidence interval around the difference between the proportions of the derivation group and the validation group; DNR = do not resuscitate; DNI = do not intubate; NCR = no cardiopulmonary resuscitation; CPR = cardiopulmonary resuscitation.

presence or absence of a concept.²⁰ Despite their advantages over simple keyword searches, natural language understanding tools require specialized parsing programs that are capable of applying domain knowledge to determine whether a term is represented in a text-based document. In our study, the keyword search missed a few cases in which the semantic capabilities of a natural language understanding method may have succeeded. Our keyword-based approach, however, is a simple, cost-effective, yet quite accurate method that can be implemented by researchers using a commonly available database or word processing tools.

Our study has several limitations. We considered only pneumonia patients for this study. As DNR order rates vary among different diseases,^{21,22} an alternative study design may have examined a DNR keyword search for all hospitalized patients independent of their disease status. Although it remains to be demonstrated, we do not believe that the terminology used to document DNR status varies among different diseases during a certain time period, which would lead to a change in performance of the DNR keyword search and bias our results in an unknown direction. We believe that pneumonia is a reasonable choice for the purpose of our study as the frequency of DNR orders is relatively high in pneumonia patients compared with other diseases.^{21,22} In addition, patients with pneumonia can have a variety of concomitant chronic diseases or conditions that may warrant end-of-life discussions. It is not uncommon that a DNR status discussion between patient and physician is initiated as a re-

sult of the patient's underlying disease and general condition, rather than the pneumonia episode.

Physician-based documentation bias may be present as this study included reports from only a single institution; however, the long study period during which many different physicians provided and documented care makes documentation bias less likely. For comparison, pneumonia patients from a study that included four different hospitals (1991–1994), had a comparable average age for DNR patients, a lower DNR order prevalence (22.1%), and a slightly lower mortality rate (6.6%).²² DNR order prevalence was similar in another study (28.9%), which examined 23,709 pneumonia patients over a seven-year period (1991–1997).²³

We did not examine additional factors such as the timing of DNR orders (early versus late DNR orders), the particular treatment preferences of patients, or the reasons a DNR order was written. Such detailed analyses are beyond the capabilities of an uncomplicated keyword search and may continue to require detailed abstraction from chart review.

Conclusion

This study examined the ability of an uncomplicated, electronic search of dictated reports to identify patients with a DNR order written during their hospitalization. If DNR order information is documented in the patients' dictated reports, the keyword search is a feasible and accurate approach to electronically detect patients with a written

DNR order. It may provide a minimum estimate of the patients in a study with DNR orders and enable investigators to evaluate bias or confounding attributable to the inclusion of these patients. The method may reduce the workload of a manual chart review, which remains necessary for DNR patients whose dictated reports do not mention DNR status.

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